

Trends and prediction in daily incidence of novel coronavirus infection in China, Hubei Province and Wuhan City: an application of Farr's law

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Abstract

Background: The recent outbreak of novel coronavirus (2019-nCoV) has infected tens of thousands of patients in China. Studies have forecasted future trends of the incidence of 2019-nCoV infection, but appeared unsuccessful. Farr's law is a classic epidemiology theory/practice for predicting epidemics. Therefore, we used and validated a model based on Farr's law to predict the daily-incidence of 2019-nCoV infection in China and 2 regions of high-incidence.

Methods: We extracted the 2019-nCoV incidence data of China, Hubei Province and Wuhan City from websites of the Chinese and Hubei health commissions. A model based on Farr's law was developed using the data available on Feb. 8, 2020, and used to predict daily-incidence of 2019-nCoV infection in China, Hubei Province and Wuhan City afterward.

Results: We observed 50,995 (37001 on or before Feb. 8) incident cases in China from January 16 to February 15, 2020. The daily-incidence has peaked in China, Hubei Providence and Wuhan City, but with different downward slopes. If no major changes occur, our model shows that the daily-incidence of 2019-nCoV will drop to single-digit by February 25 for China and Hubei Province, but by March 8 for Wuhan city. However, predicted 75% confidence intervals of daily-incidence in all 3 regions of interest had an upward trend. The predicted trends overall match the prospectively-collected data, confirming usefulness of these models.

Conclusions: This study shows the daily-incidence of 2019-nCoV in China, Hubei Province and Wuhan City has reached the peak and was decreasing. However, there is a possibility of upward trend.

The recent outbreak of novel coronavirus (2019-nCoV) in China has infected about 38,800 patients, and claimed 1113 lives. Studies have forecasted future trends of the infection incidence of coronavirus,¹ but appeared unsuccessful, likely owing to the recently-implemented aggressive interventions.² Farr's law is a classic epidemiology theory/practice for predicting epidemics.^{3,4} Therefore, we used and validated a model based on Farr's law to predict the daily-incidence of 2019-nCoV infection in China and 2 regions of high-incidence.

Methods | We extracted the 2019-nCoV incidence data of China, Hubei Province and Wuhan City from websites of the Chinese and Hubei health commissions, respectively. The model was developed based on the data available on Feb. 8, 2020, and compared with the prospectively collected data afterward. According to prior reports,^{4,5} the ratio 1 was the ratio of a given day's incidence over that of the day before. Dividing the ratio 1 of one day and the day before resulted in ratio 2. The possible normality of the ratio 2 was examined using Skewness and Kurtosis tests after various data transformations. After identifying the best-fit data transformation format, we examined the potential linear and log-linear associations of incidence with

time. Assuming the future ratio 1's and 2's would be the same as the mean of the past five dates and ratio 2's the same as the mean of the last 10 days, we predicted the ratio 1's and daily incidence. Statistical analyses were conducted using Stata (version 15) and Joinpoint (NCI). All P values were two-sided and a $P < .05$ was considered statistically significant. The study is exempt from institutional review board's review due to the use of publically available and de-identified data.

Results | The daily-incidence was available for China from January 16 to February 11, 2020, for Wuhan and Hubei from January 11 to February 11. Among various data transformation formats, natural-logarithm-transformed incidence data were of normal distribution, without significant log-linear or linear association. The mean of ratio 2 before February 8, 2020 was 0.944 (quartile 0.886-1.051) for China, 0.982 (quartile 0.744-1.317) for Wuhan and 0.948 (quartile 0.768-1.207) for Hubei Province. The future incidence was predicted based on the mean or quartiles of ratio 2 and subsequently inferred ratio 1's. The daily-incidence significantly decreased after February 8 in all regions, and would continue decreasing until reaching zero on February 25. Given the lower quartile (25%) of ratio 2, the incidence may reach zero by February 20,

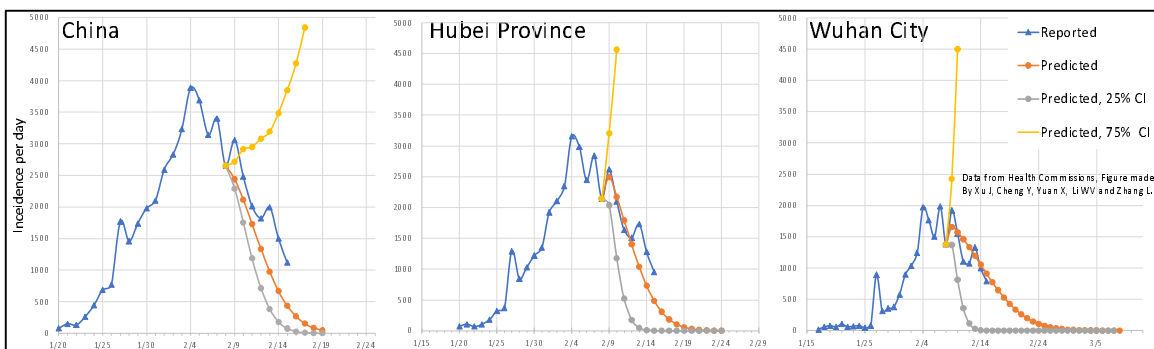


Figure. The reported and predicted daily incidence of 2019 novel coronavirus infection in China, Hubei Province and Wuhan City. The predicted daily incidence would reach zero on February 25 for China and Hubei Province, but on March 8 for Wuhan City, due to different ratio 2's. CI, confidence interval.

while based on the upper quartile (75%) of ratio 2, the daily-incidence will keep increasing and reach 3000 on February 25 (**Figure**). Hubei Province and Wuhan City had a similar downward trend (**Table**). The prospectively collected daily-incidence after February 8 appeared to fall in the predicted quartiles in all 3 selected regions.

Discussion | Mostly using Farr's law, we estimated the quartiles of 2019-nCoV daily-incidence in China, Hubei Province and Wuhan City, and predicted the daily-incidence of these regions. Our results imply that the daily-incidence has reached its peak and will likely decrease continuously in China, Hubei Province and Wuhan City, while the predicted 75% CI of their daily-incidence had an upward trend. Therefore, governments, healthcare providers and residents should be cautiously optimistic, and recognize the potential upward trend of daily-incidence. A rapid growth in daily-incidence may occur when the residents of high-prevalence regions, such as Hubei Province, return to their workplaces in low-prevalence regions at the end of Chinese New-Year holidays. Extreme caution thus should be used to prevent such an upward trend.

Limitation includes possible oversimplification of the disease's natural history by this model. However, our prospectively-collected data and recent works proved the usefulness of the Farr's law.⁵ This simple yet powerful method has also successfully predicted the trends in incidence of opioid overdose in the U.S.⁴

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[s](#), as new prospectively collected incidence data become available.

Author Contributions: Drs Xu and Zhang had full access to all of the data in the study and equally takes responsibility for the integrity of the data and the accuracy of the data analysis. They are both senior authors. Drs Xu and Cheng both contributed equally and should be considered co-first authors.

Concept and design: Xu, Zhang.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Xu.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Li, Zhang.

Supervision: Xu, Zhang.

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Table. Daily incidence of diagnosed novel coronavirus cases in China and selected areas, Jan. 17 to Feb. 11, 2020, with prediction to March 8, 2020 By Xu J, Cheng Y, Yuan X, Li WV and Zhang L.

Date	China				Hubei province				Wuhan City, Hubei			
	Incidence (per day)	Predicted	Ratio 1 ^a	Ratio2 ^b	Incidence (per day)	Predicted	Ratio 1 ^a	Ratio2 ^b	Incidence (per day)	Predicted	Ratio 1 ^a	Ratio2 ^b
1/17/2020									17			
1/18/2020									59		3.471	
1/19/2020									77		1.305	0.376
1/20/2020	77				72				60		0.779	0.597
1/21/2020	149		1.935		105		1.458		105		1.750	2.246
1/22/2020	131		0.879	0.454	69		0.657	0.451	62		0.590	0.337
1/23/2020	259		1.977	2.249	105		1.522	2.316	70		1.129	1.912
1/24/2020	444		1.714	0.867	180		1.714	1.127	77		1.100	0.974
1/25/2020	688		1.550	0.904	323		1.794	1.047	46		0.597	0.543
1/26/2020	769		1.118	0.721	371		1.149	0.640	80		1.739	2.911
1/27/2020	1771		2.303	2.060	1291		3.480	3.030	892		11.150	6.411
1/28/2020	1459		0.824	0.358	840		0.651	0.187	315		0.353	0.032
1/29/2020	1737		1.191	1.445	1032		1.229	1.888	356		1.130	3.200
1/30/2020	1982		1.141	0.958	1220		1.182	0.962	378		1.062	0.940
1/31/2020	2102		1.061	0.929	1347		1.104	0.934	576		1.524	1.435
2/1/2020	2590		1.232	1.162	1921		1.426	1.292	894		1.552	1.019
2/2/2020	2829		1.092	0.886	2103		1.095	0.768	1033		1.155	0.744
2/3/2020	3235		1.144	1.047	2345		1.115	1.019	1242		1.202	1.041
2/4/2020	3887		1.202	1.051	3156		1.346	1.207	1967		1.584	1.317
2/5/2020	3694		0.950	0.791	2987		0.946	0.703	1766		0.898	0.567
2/6/2020	3143		0.851	0.895	2447		0.819	0.866	1501		0.850	0.947

2/7/2020	3399		1.081	1.271	2841		1.161	1.417	1985		1.322	1.556
2/8/2020 ^c	2656		0.781	0.723	2147		0.756	0.651	1379		0.695	0.525
2/9/2020	3062	2439	0.918	0.944	2618	2494	0.965	0.982	1921	1659	0.965	0.982
2/10/2020	2478	2115	0.867	0.944	2097	2171	0.947	0.982	1552	1571	0.947	0.982
2/11/2020	2015	1730	0.818	0.944	1638	1792	0.930	0.982	1104	1462	0.930	0.982
2/12/2020	1820	1336	0.772	0.944	1508	1402	0.913	0.982	1072	1335	0.913	0.982
2/13/2020	1995	974	0.729	0.944	1728	1040	0.897	0.982	1330	1198	0.897	0.982
2/14/2020	1503	670	0.688	0.944	1282	731	0.881	0.982	1001	1055	0.881	0.982
2/15/2020	1121	435	0.649	0.944	955	487	0.865	0.982	793 ^d	912	0.865	0.982
2/16/2020		266	0.613	0.944		308	0.849	0.982		775	0.849	0.982
2/17/2020		154	0.578	0.944		185	0.834	0.982		646	0.834	0.982
2/18/2020		84	0.546	0.944		105	0.819	0.982		529	0.819	0.982
2/19/2020		43	0.515	0.944		56	0.804	0.982		425	0.804	0.982
2/20/2020		21	0.486	0.944		29	0.790	0.982		336	0.790	0.982
2/21/2020		10	0.459	0.944		14	0.775	0.982		260	0.775	0.982
2/22/2020		4	0.433	0.944		6	0.761	0.982		198	0.761	0.982
2/23/2020		2	0.409	0.944		3	0.748	0.982		148	0.748	0.982
2/24/2020		1	0.386	0.944		1	0.734	0.982		109	0.734	0.982
2/25/2020		0	0.364	0.944		0	0.721	0.982		78	0.721	0.982
2/26/2020		0	0.344	0.944		0	0.708	0.982		56	0.708	0.982
2/27/2020		0	0.324	0.944		0	0.695	0.982		39	0.695	0.982
2/28/2020		0	0.306	0.944		0	0.683	0.982		26	0.683	0.982
2/29/2020		0	0.289	0.944						18	0.670	0.982
3/1/2020		0	0.273	0.944						12	0.658	0.982
3/2/2020		0	0.257	0.944						8	0.646	0.982
3/3/2020		0	0.243	0.944						5	0.635	0.982

3/4/2020	0	0.229	0.944	3	0.623	0.982
3/5/2020	0	0.216	0.944	2	0.612	0.982
3/6/2020	0	0.204	0.944	1	0.601	0.982
3/7/2020	0	0.193	0.944	1	0.590	0.982
3/8/2020	0	0.182	0.944	0	0.579	0.982

Note: The case number may be changed due to clerical error or change of the diagnosis in early days.

